

State of the Art Reinforcement for Concrete Bridge Decks

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Overview

- Background
- Reinforcements
 - MMFX 2
 - Nuovinox NX
- Ft. Knox Bridge Deck Projects
 - Culvert replacement
 - Mill Creek Bridge
- Summary



Background

- Deck corrosion is problematic and costly for vehicular bridges
- The Army alone has more than 1,500 bridges on its installations, with the majority having reinforced concrete decks
- FHWA Report RD-01-156 states that approximately one quarter of the direct cost of corrosion of bridges is maintenance and capital costs for concrete decks
- FHWA studies have also found that indirect costs to the user due to traffic delays, and lost productivity can be up to 10 times higher than the direct costs of repair and maintenance



Microcomposite Martensitic Ferretic Steel (MMFX 2)

- Initial proprietary technology developed at the University of California Berkeley by Professor Gareth Thomas
- Material composition resistant to corrosion

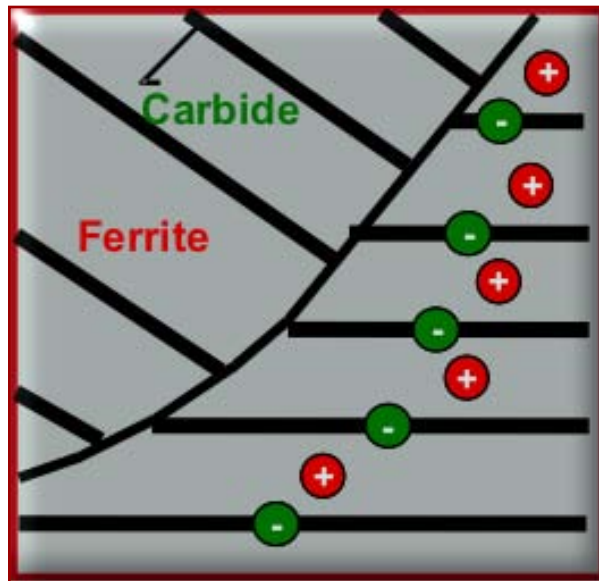


Courtesy MMFX

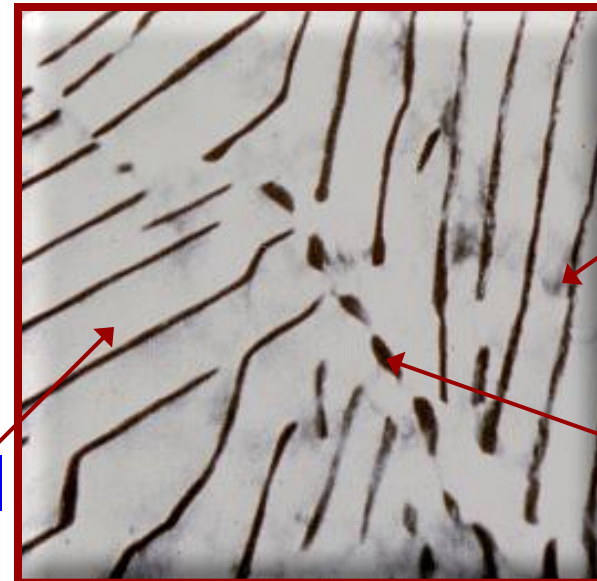


Corrosion of Pearlitic Steel

Schematic of Micro Galvanic Cells in the Ferrite-Iron Carbide Microstructure



Transmission Electron Microscope (TEM) Micrograph of the Ferrite – Iron Carbide Microstructure



Carbide (Typical)

Grain Boundary with Carbides

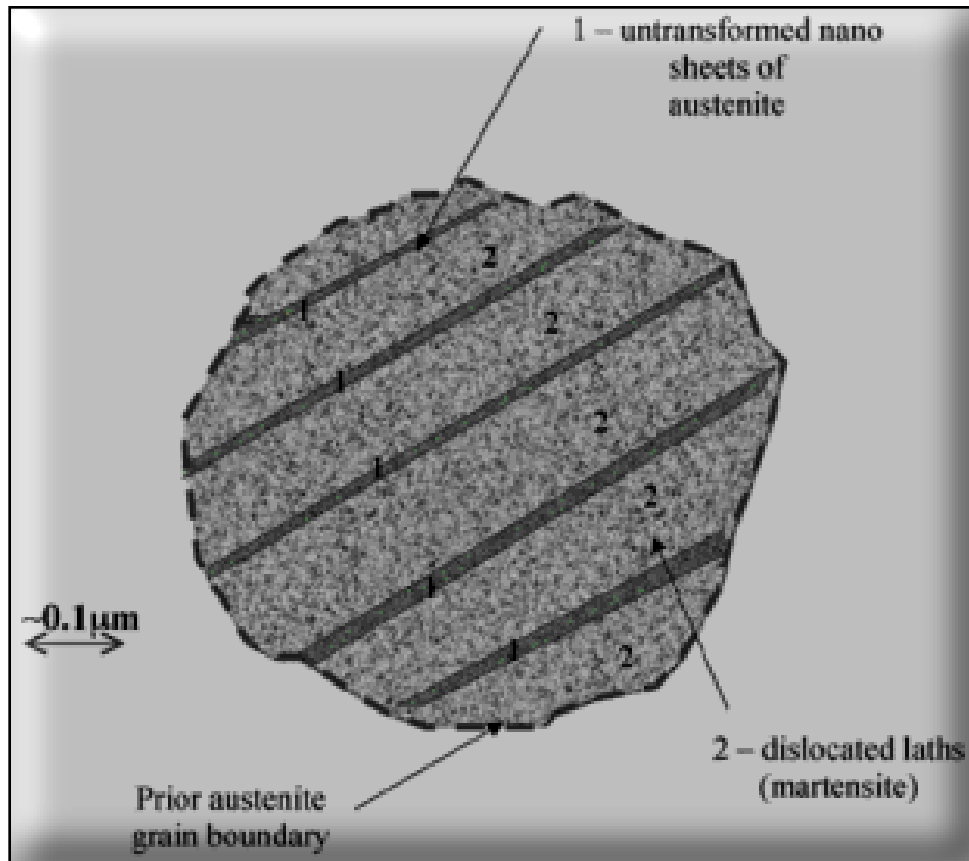
Ferrite

Microgalvanic Cell Formation Between Iron-Carbide and Ferrite Phases

Corrosion Can Be Minimized By Avoiding Microgalvanic Cell Formation



Microcomposite Steel



Microcomposite Steels, Packet Lath Martensite

Dislocated laths of martensite enveloped
by stable retained
austenite films

**CARBIDE FREE
MICROSTRUCTURE**
to Eliminate Formation of
Microstructural Galvanic Cells



Mechanical Properties

MMFX 2

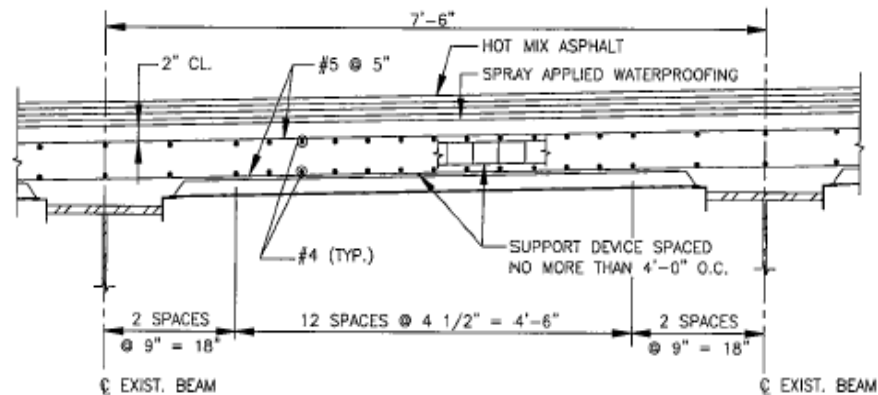
- Mechanical
 - $s_{y(0.2\%)} > 100 \text{ ksi (690 MPa)}$
 - $s_T > 150 \text{ ksi (1,030 MPa)}$
 - $e > 7\%$
- Conforms to ASTM C 035A/1035M-04 for concrete reinforcement



Advantage of Higher Strength

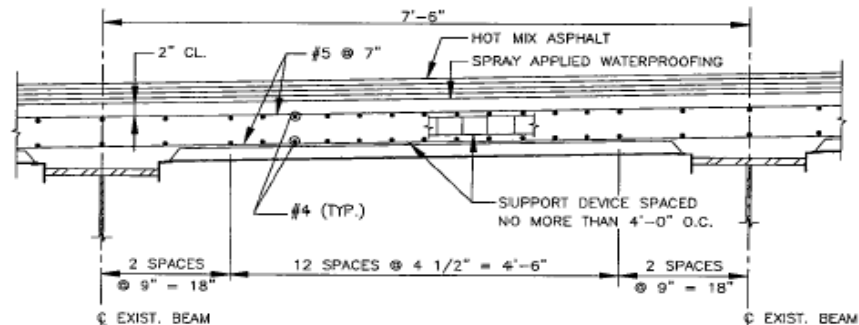
Typical Grade
60 Design

DECK SECTION WITH GRADE 60 REINFORCEMENT:



Design
with 75 ksi limit
(20% Less Steel)

DECK SECTION WITH GRADE 75 REINFORCEMENT:



NOTES:

1. ROADWAY DECK SLAB SHALL BE 4000 PSI-3/4"-565 LB HP CEMENT CONCRETE.
2. #4 LONGITUDINAL REINFORCEMENT SHALL BE PLACED PARALLEL TO THE ϵ OF CONSTRUCTION.
#5 MAIN REINFORCEMENT SHALL BE PLACED PERPENDICULAR TO THE ϵ OF CONSTRUCTION.
3. ALL REINFORCEMENT AND SUPPORTING DEVICES SHALL BE MMFX 2 STEEL.

Courtesy MMFX



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Corrosion Resistance

- MMFX 2 rebar's corrosion resistance has been reported at between 5 and 6 times that of conventional A615 rebar
- MMFX 2 rebar's corrosion rate has been reported to be between 1/3 and 2/3 that of conventional A615 rebar
- MMFX 2 rebars have expected 75+ years service life



Nuovinox NX-SCR

- 316L Stainless steel cladding with carbon steel core
- Patented “green” process bonds stainless steel to carbon steel
- Optimizes stainless steel’s very high corrosion resistance with the mechanical properties and elastic modulus characteristics of low alloy carbon steel
- Half the cost of stainless steel reinforcement while providing comparable strength and corrosion resistance



Manufacturing Process



Properties NX-SCR

- Produced in 1/8 in. diameter increments ranging from a #4 through to a #10
- Stainless Steel thickness between .014 and .035 in. (2 to 7 times the minimum .007 in. requirement for ss clad rebar)
- Standard length: 39.5 ft
- Nuovinox stainless clad rebar conforms to AASTO MP13 (this code is based on ASTM A955 and ASTM A615)



Corrosion Resistance NX-SCR

- Compatible with 316L Stainless Steel
- High service life (>100 years)
 - Epoxy coated rebar corrosion life between 20 and 40 years
 - Based on bridge model assuming surface chloride concentration of 26 lb/yd³
- Expected to remain corrosion free at chloride concentrations up to 15 lb/yd³



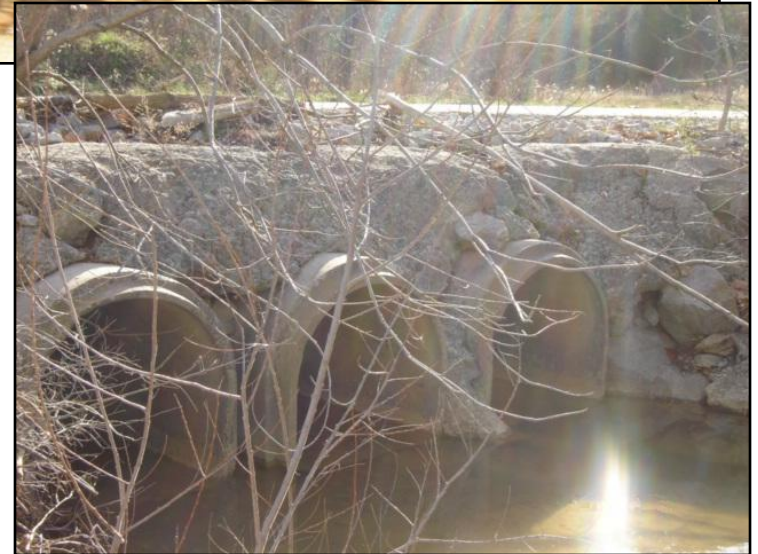
Bridge Deck Replacement Ft. Knox, KY

- Replacement of two bridge decks where road salts are used for de-icing
- One of two types of state-of-the-art corrosion resistant reinforcement, MMFX 2 and Nuovinox NX-SCR, will be used at each bridge
- Installation of each type of rebar at nearly identical locations will allow for a side-by-side comparison and evaluation of the rebar performance
- Data will be collected for multiple years to monitor corrosion
- Life expectancy of both types of rebar is expected to exceed 75 years



Fort Knox Culvert Bridge

- Tanks and regular vehicular traffic use this bridge
- Slated to be replaced in the near future with a single-span bridge
- Subjected to de-icing salts



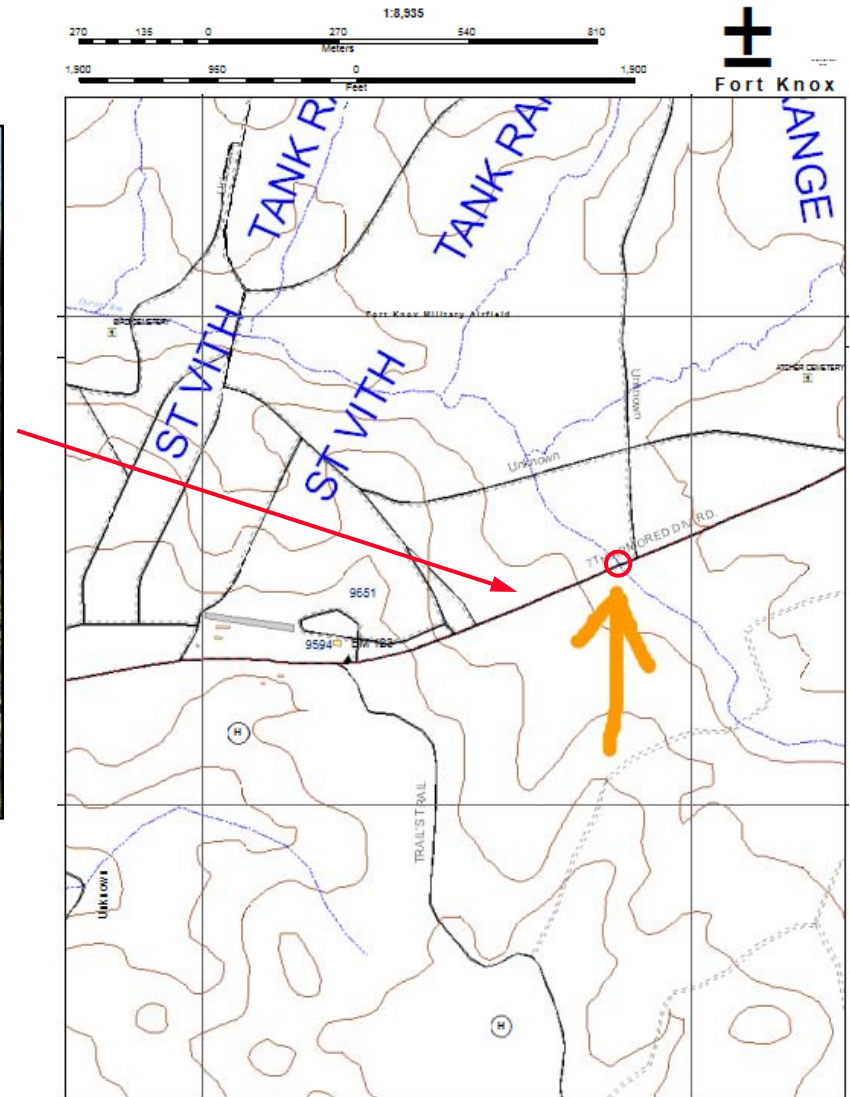
Location



- Culvert Replacement



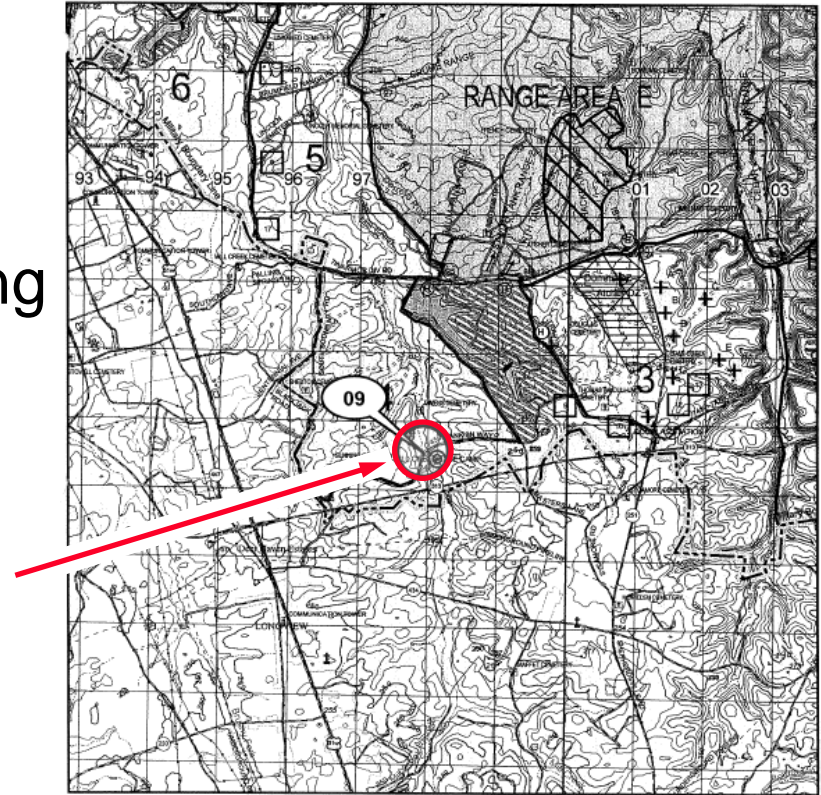
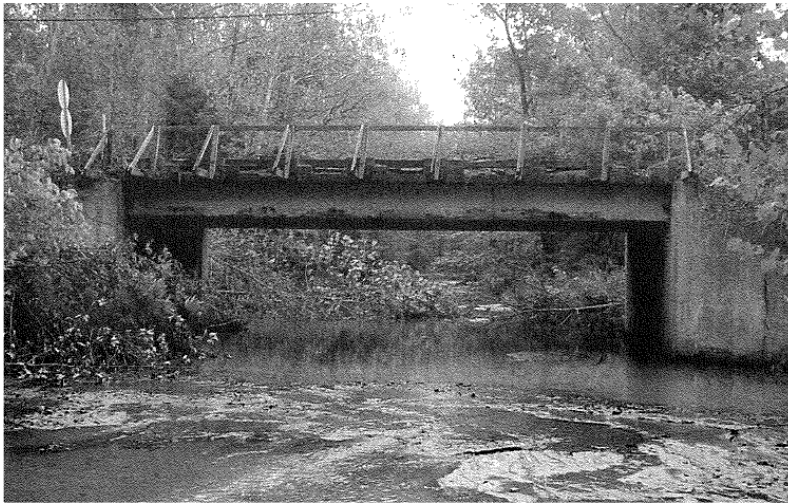
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Bridge Over Mill Creek

- Two lane bridge, wooden deck
- Total replacement including a concrete deck



Product

- Positive results observed as part of this project will result in recommended changes in ACSIM's Installation Design Standards
- Results will also be presented to ACI, ASCE, and ASSHTO



Summary

- Single-span bridges to be constructed in Fort Knox, KY will test longevity and durability of two types of rebar
- MMFX 2 is a novel reinforcing steel; a low in carbon, chromium, microcomposite steel that conforms to ASTM C 1035A/1035M-04 for concrete reinforcement
- Nuovinox is a type of long-term rebar that consists of stainless steel cladding with a carbon steel core, providing similar properties to stainless steel rebar at a reduced cost
- These two state-of-the-art reinforcing bars have the potential to reduce initial costs, increase the lifespan of bridge decks and reduce maintenance costs due to corrosion of rebar

